Contributions of Household Chemicals to Sewage and Their Relevance to Municipal Wastewater Systems and the Environment

Products containing inorganic and organic compounds are regularly used in household products, are produced in high volumes, and end up in municipal wastewater systems, representing a potential threat to the environment.

This study identified organic compounds from household products that may be present in municipal wastewater.

Neither the toxicity nor the fate of high production volume (HPV) chemicals in the wastewater treatment process, nor their relationship to environmental health, is well understood. The lack of information, both on the safety of HPV chemicals and organic compounds used in household commodities and on the amount of hazardous substances being released into the environment during use and disposal, is posing a major challenge to the water industry.

This study investigated the occurrence and fate of HPV household chemicals in wastewater systems, and comprehensively reviewed HPV organic chemicals and their contributions to municipal wastewater treatment systems. The occurrence was studied in raw sewage and final treated effluents at full-scale treatment plants. Researchers also identified and developed quantitative structure activity and property relationships (QSPRs) to model the behavior of individual compounds through treatment processes.

The U.S. EPA has identified approximately 500 (HPV) chemicals used in materials like auto, home maintenance, and personal products. WERF researchers selected 26 compounds for study, focusing on organic compounds. The selected compounds are likely to be present in domestic wastewater due to their physicochemical properties and reported environmental fate. Of the compounds, 20 were consistently detected in raw influents of full-scale wastewater treatment plants. The study also examined two additional compounds: linear alkylbenzene sulfonate (LAS), which can function as a model for complex mixtures, and triclocarban, which can serve as an example of an emerging contaminant.

They were considered in two tiers: Tier 1 compounds have production volumes greater than one million pounds per year, and less than a million pounds of each Tier 2 compound is produced each year.

HPV Household Chemical Removal Depends on Treatment Process

Researchers studied the efficacy of advanced wastewater treatment processes to remove and destroy the selected compounds. Their sites included regional variations as they examined the removal effectiveness of individual processes comprising an overall process train at six participating facilities in the western United States.

This research found that biological treatment generally resulted in partial or complete

BENEFITS

- Provides a comprehensive compilation of high-production volume organic chemicals commonly used in household products.
- Provides a validated framework to identify household chemicals potentially found in sewage.
- Provides assurance that biological and chemical wastewater treatment processes are capable of achieving a high removal of targeted household chemicals.

RELATED PRODUCTS

Fate of Pharmaceuticals and Personal Care Products through Wastewater Treatment Processes (03CTS22UR)

Moving Towards an Innovative DNA Technology for Detection of Pharmaceuticals in Reclaimed Water (01HHE21T)

RELATED ONGOING RESEARCH

Evaluation of QSPR Techniques for Wastewater Treatment Processes (U2R07)

AVAILABLE FORMAT

Soft cover, CD ROM, and online PDF.

TO ORDER

Contact WERF at 703-684-2470 or visit www.werf.org and click on Publications.

WERF Subscribers:
Your first copy of this report is free. Additional copies are $10 each or download unlimited free PDFs at www.werf.org.

Non-Subscribers:
Hardcopy: $175 PDF: $50

Refer to: **STOCK NO. 03CTS21UR**

For more information, log on to **www.werf.org**

removal (>80%), indicating that it is a good treatment option for HPV household chemicals. Researchers then evaluated the removal or transformation of particular HPV chemicals by biological treatment (activated-sludge and MBR), disinfection (UV, chloramines, chlorine), and advanced oxidation (ozone and ozone/hydrogen peroxide) processes. MBR and activated-sludge treatments generally removed all compounds similarly.

For conventional disinfection processes, chlorination represents a process for partial transformation of these compounds and a second barrier, although it is likely that halogenated by-products are formed during this process. Chloramine and UV disinfection processes are not viable removal barriers. Ozonation and ozone/hydrogen peroxide treatments performed similarly and are additional barrier options where higher effluent quality is desired. However, they don't represent a 100% barrier for all compounds (e.g., vanillin).

Researchers studied the efficacy of advanced wastewater treatment processes to remove and destroy the selected compounds.

HPV Household Chemicals Detected in Raw Sewage and Wastewater Effluents

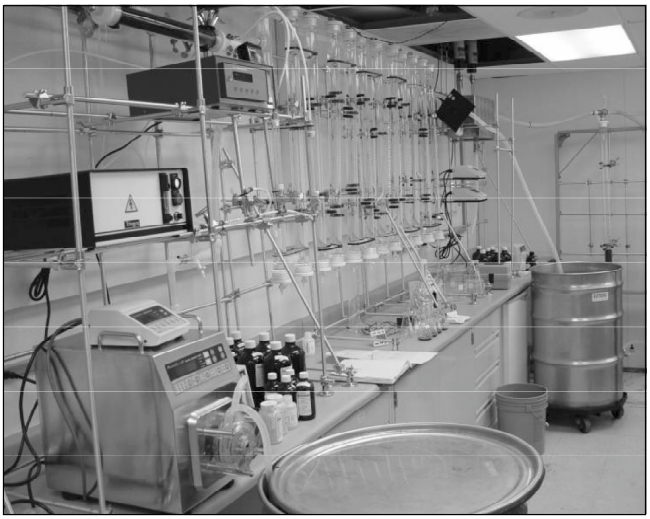
Most of the compounds occurred at concentrations comparable to the occurrence of pharmaceutical residues. The average concentration of LAS in raw sewage represented the highest observed concentrations of all compounds targeted in this study, approaching 6 mg/L and reduced in secondary treated effluents to approximately 4,000 ng/L.

Daily mass loading variations of all Tier 1 compounds suggested a relatively constant discharge of household chemicals to sewage. Discharge was directly coupled to water consumption and thus linked to consumer discharge. Daily mass loadings of Tier 2 compounds were significantly lower than Tier 1 compounds but also followed the general diurnal trend.

Occurrence in the liquid phase of sewage seems to depend on both production volume and compound properties. For example, of the three compounds with production volumes between 10 and 50 million pound per year (BHT, dibutyl phthalate, and 2-phenoxyethanol), 2-phenoxyethanol is the most water soluble (LogKow of 1.16) and exhibits the highest mass loading in raw sewage.

QSPR Models can Assess Fate and Treatment

The removal of an organic compound during treatment depends on its structure. Quantitative structure activity and property relationship (QSPR) models mathematically quantify the correlations between a fate parameter (e.g., degradation rate constant), and molecular descriptors of a compound (e.g., dipole moment and connectivity indices). QSPRs can be coupled with chemical mass balance models to quickly assess the fate and treatment of new and existing chemicals within wastewater treatment systems. Researchers evaluated the potential for various QSPRs to predict the treatability of new compounds.



Ozonation laboratory-scale experimental set-up at the Southern Nevada Water Authority.

Several existing QSPRs that are relevant to wastewater treatment removal routes—reactivity, phase partitioning, and physical separation—can be applied to the prediction of the removal of compounds through wastewater treatment trains.

QSPRs should be evaluated further for their applicability to a range of organic compounds and realistic environmental conditions. Additional research can determine which QSPR(s) best chemically and/or physically describe an organic compound's potential to be removed by a particular mechanism. We also need to generate fate parameter data, such as biodegradation and chlorination removal rates. Uniformly measured treatment data for some removal mechanism is also needed. QSPRs should be incorporated into appropriate mass balance models and these models need to be validated by full-scale treatment data.

Table 1. A Sample of Target Compounds Selected for this Study

Compound	Application
Tier 1	
2,6-Di-t-butyl-p-cresol (BHT)	skin care, hobby supplies
Dibutyl phthalate	plasticizer, finish, nail care
Atrazine	herbicide
4,4-Isopropylidenediphenol (Bisphenol A)	plasticizer, epoxy, glue
Benzophenone	car wash, facial products
Benzophenone-3 (Oxybenzone)	skin care, insect repellent
Triclosan	antibacterial, soap, lotion
Vanillin	fragrance, cosmetics, various
o-Phenylphenol	germicide, fungicide
2-Phenoxyethanol	preservatives, cosmetics, fragrance, various
Hexabromocyclododecane	flame retardant
Tier 2	
Simazine	herbicide, anti-algae products
N,N-Diethyl-meta toluamide (DEET)	insect repellent, industrial
Hydrocortisone	anti-itch cream
Butylated hydroxyanisole (BHA)	anti-oxidant, various
3-Indolebutyric acid	fertilizer, Miracle Gro™
Camphor	fragrance, various
Menthol	fragrance, various
2-Methylresorcinol	hair color, cosmetics
Isobutylparaben	preservative, cosmetics, various
Acriflavine	antiseptic, pesticide
Trifluralin	herbicide
2,3,4,5 Bis(2-butylene) tetrahydro 2-furaldehyde (MGK-11)	insect repellent
Propylparaben	preservative, various
Model Compounds	
Triclocarban	antibacterial, soap, deodorant
Linear alkylbenzene sulfonate (LAS)	surfactant, various
Indicator Compounds	
Primidone	Antiepileptic drug
Phenacetine	Anti-inflammatory drug
Carbamazepine	Antiepileptic drug
2-Naphthol	Industrial chemical
Fenofibrate	Blood lipid regulator
Gemfibrozil	Blood lipid regulator
Propyphenazone	Anti-inflammatory drug
Sulfamethoxazole	Antibiotic drug
Ibuprofen	Anti-inflammatory drug
Naproxen	Anti-inflammatory drug
Diclofenac	Anti-inflammatory drug

Follow-On Research

In a follow-on research project entitled *Evaluation of QSPR Techniques for Wastewater Treatment Process* (WERF U2R07), researchers are evaluating existing QSPR techniques for the removal of trace organic compounds by the following major removal routes during conventional wastewater treatment: biotransformation, biosolids sorption, and chlorine oxidation. Further, the researchers may refine or develop QSPR models for the these removal mechanisms. The proposed study is scheduled for completion in December 2010.

A Note About this Report

This report includes a hardcopy of the final report as well as a High Production Chemical Database Excel spreadsheet on CD ROM. Both are available at www.werf.org.

The research on which this report is based was funded in part by the U.S. Environmental Protection Agency (U.S. EPA) through Cooperative Agreement No. CR-831559-01 with the Water Environment Research Foundation (WERF). Unless an U.S. EPA logo appears on the cover, this report is a publication of WERF, not U.S. EPA. Funds awarded under the agreement cited above were not used for editorial services, reproduction, printing, or distribution.

CONTRACTOR

Jörg E. Drewes, Ph.D.
Colorado School of Mines

Shane Snyder, Ph.D.
Southern Nevada Water Authority

PROJECT TEAM

Eric Dickenson, Ph.D.
Terry Jennings, M.S.
Tanja Rauch-Williams, Ph.D.
Colorado School of Mines

Brett Vanderford
Rebecca Trenholm
Dawn Lei, Ph.D.
Southern Nevada Water Authority

PROJECT SUBCOMMITTEE

Steve Rogowski (Chair)
Metro Wastewater Reclamation District of Denver

Kenneth E. Banks, Ph.D.
City of Denton, TX

Rolf Halden, Ph.D., P.E.
Johns Hopkins University

Robert Hannah
GlaxoSmithKline

R. David Holbrook, Ph.D., P.E.
National Institute of Standards and Technology

David Lordi, Ph.D.
Metropolitan Water Reclamation District of Greater Chicago

Glynda L. Mercier, P.E.
GlynData

Brad Price, Ph.D.
The Procter & Gamble Company

Rich Sedlak
The Soap and Detergent Association

Gregory Sayles, Ph.D.
U.S. EPA National Risk Management Research Laboratory

COLLABORATORS

WateReuse Foundation